NEW ENGLAND DIVISION
CORPS OF ENGINEERS
PLANNING AND REPORTS BRANCH - ENGINEERING DIVISION

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F.C.S. Memorandum No. 53 - General - 2

SUBJECT: Flood Control Studies - Kennebec River Basin.

1. Reference. - This memorandum supersedes F.C.S. Memorandum No. 52 - General - 4, of the same subject due to revisions in the plan for power development, and the introduction of a different approach to the evaluation of flood control benefits derived from the regulation of a power reservoir.

2. Purpose. - This report describes the analysis of floods on the Kennebec River to determine their origin and contributions from principal tributaries, the frequency of floods, and the flood reductions provided by the power and flood control projects discussed in the preliminary report submitted by this office to NENYIAC, and the land treatment program of the Department of Agriculture. A brief description of the methods of analysis is included with graphs and tabulations to show the results of the study. The data pertaining to frequencies and flood reductions are utilized by the Damage Section to derive the annual benefits for the various projects.

3. History of Floods. - The six greatest floods of record on the Kennebec River at Waterville, Maine (drainage area 4,200 square miles) are as follows:

December 16, 1901	157,000 c.f.s.
March 19, 1936	154,000 "
May 1, 1923	135,000 "
March 2, 1896	113,000 "
March 28, 1953	110,000 "
April 15, 1895	103,000 "

4. <u>Flood Data</u>. - As noted in the previous paragraph, records of floods were maintained at Waterville for many years, principally by the Hollingsworth and Whitney Co. The U.S. Geological Survey began to install gaging stations in the early 1900's and now have developed a network of recording stations in the Kennebec River Basin. Data for recent flood hydrographs were also obtained from the manufacturers and power companies on the Kennebec River. In some cases the accuracy of this information is questionable due to the difficulties in developing rating curves for the complex and varied means of discharge controls. The flood of March 1936 provides the first major flood with sufficient discharge records for detail analysis. Adjustment to the records were made for ice jams which caused the maximum flood stages to be several feet higher than they would have been for corresponding natural flows.

5. <u>Flood Frequencies</u>. - The frequencies of peak discharges were determined at all gaging stations in the basin (except Moosehead Lake outflow) in accordance with the procedure described in Civil Works Engineer Bulletins 51-1 and 51-14, and summarized in F.C.S. Memorandum No. 52 - General - 3, "Flood Frequency Studies in New England". The frequency data

for the gaging stations were used to derive frequency curves applicable to damage zones selected for economic studies. A tabulation of natural discharge-frequency data for the damage zones is shown in Table 1. Adjustments were made to frequency data for the Dead River at The Forks(Damage Zone 21) and at Bingham (Damage Zone 19) to compensate for the effect of the relatively new Flagstaff Reservoir on the Dead River. Hence, the tabulated frequency data reflect the regulation at Flagstaff Reservoir similar to the flood control provided by Moosehead Lake during the past years.

6. Monthly Flood Potential Indices. - The term "Monthly Flood Potential Indices" was coined to indicate the monthly chance of occurrence of floods expressed in percent. The sum of the twelve monthly indices equals 100%. The indices represent the monthly potentialities of floods and are weighted values that consider the number of floods that may occur in each month with the severity or magnitude of the flood. Various methods were used to develop the indices with the final values selected from weighing the results of the different methods. The following methods were used:(a) by relating the areas under monthly discharge-frequency curves plotted on arithmetic-probability paper, (b) by comparing the summation of all monthly discharges greater than a two year flood, and (c) by relating the monthly damages in dollars that would have occurred at some typical damage zone from the records of the past floods. Consideration was also given to the history of major storms in New England and their seasonal distribution. Three sets of indices were adopted as follows:

MONTHLY FLOOD POTENTIAL INDICES

Month	Maine: Kennebec Penobscot	Maine: Androscoggin Saco	N.H., Vt., Mass. and Conn.
January	1	1	2
February	1	1	2
March	13	15	31
April	28	38	35
May	35	24	8
June	9	6	4
July	1	1	1
August	1	1	1
September	4	5	6
October	1	1	2
November	4	4	4
December	2	3	4
	100	100	100

7. Analysis of Floods. - In studying the hydrology of a river basin, it is essential to ascertain the origin and development of floods. Knowledge of the magnitude and timing of tributary flood contributions is necessary in order to evaluate the flood control effectiveness of various projects. The determination of the flood-producing potentialities and characteristics of the Kennebec River Basin were based on a study of the data collected during the floods of March 1936, November 1950 and April 1951. These floods and

their magnitude at Waterville are as follows:

March 1936	154,000 c.f.s.
November 1950	75,000 c.f.s.
April 1951	72,500 c.f.s.

8. The Kennebec River was divided into basin sub-divisions (See Plate 1) and routing reaches for hydraulic analyses. The limits of the reaches were taken at U.S.G.S. gaging stations, at the mouths of the principal tributaries, and at other control points. Excellent information on the tributary contributions was provided by the gaging station records near the mouths of the principal tributaries. For ungaged areas (so-called "local areas" between known points) the flood hydrographs were developed synthetically by comparison with the hydrographs from gaged areas. The component hydrographs for the basin sub-divisions were routed to determine their contributions to the flood peak at downstream damage centers.

9. Table 2 shows the flood contributions from all major tributaries and miscellaneous local areas at Bingham, Waterville and Augusta. It is obvious that the flood-producing tributaries in the Kennebec River Basin are primarily the Carrabassett and Sandy Rivers. Austin Stream is also a high contributor considering its relatively small drainage area. Rivers of minor importance in the development of floods are the Dead and Sebasticook Rivers. Plate 3 shows the peak discharge profile for the Kennebec River for all the floods analyzed with a graphical presentation of the contributions from the various tributaries.

10. Flood Routing. - Lag-Average Flood Routing (formerly called Straddle-

Stagger) was adopted for use in the Kennebec River Basin in order to have a simple arithmetical method that could be readily derived and checked, could be easily applied to determine the effect of proposed projects; and was commensurate with the availability and accuracy of the basic data. In brief, the method (described in memorandum to Hydrology Files, dated 24 September 1952, "Straddle-Stagger Reach Routing") is emprical and involves the determination of routing coefficients for each reach, provided flood hydrographs are known at the upper and lower limits of the reach. Using the hydrographs derived by sketch-routing the coefficients for the number of periods to be averaged (Straddle), and the number of periods to be lagged (Stagger) were obtained by trial and were checked by reconstruction of the outflow hydrograph. The coefficients for each reach are tabulated in Table 3.

11. Typical Tributary Contribution Flood. - To determine the discharge reductions applicable to various projects, a synthetic flood was derived to represent the most probable development of a flood in the Kennebec River Basin. This synthetic flood is called the Typical Tributary Contribution Flood (TTCF). The storm, producing the TTCF, is assumed to be distributed throughout the basin in an isohyetal pattern similar to the average annual precipitation. A study of the storms producing the three floods analyzed in the Kennebec River (March 1936; November 1950; and April 1951) indicated that all were caused by storm patterns closely corresponding to the average annual rainfall. Hence, the tributary components in the TTCF were derived as an average of the contributions for each flood where the contributions were initially expressed as a percentage of the total peak flow at Waterville, Maine.

12. The magnitude of the TTCF is entirely relative. While it is possible to express the flood in terms of percentage of peak flows, it is difficult to visualize a flood hydrograph in such terms. The hydrographs were, therefore, arbitrarily assigned values in cubic feet per second (c.f.s.) by assuming for simplicity that the 100% flood at Waterville had a peak of 100,000 c.f.s. All tributary flows were then converted from percentages to c.f.s. contributions. The components to the flood hydrographs at Bingham and Waterville are shown on Plate 2. A graphical summary of the TTCF showing the flood discharge profile and tributary contributions is shown on Plate 3. Application of the TTCF is described in paragraph 37.

13. The peak flows of the TTCF from the tributaries were also correlated with the discharge-frequency curves. It was assumed that the peak flows of the TTCF were related to the areas under the discharge-frequency curves when plotted on arithmetic-probability paper. The probability limits for area measurement were assumed to be between 50% chance of occurrence (2 years) and 0.05% (2,000 years). Selection of these limits were based on the fact that the 50% probability flood is the flood representing the approximate beginning of damages, while the 0.05% probability is the upper limit considered in economic analyses.

14. <u>Damage Zones</u>. - In collaboration with the Damage Section, the Kennebec River and its principal tributaries were divided into damage zones, (not to be confused with routing reaches) to facilitate economic analysis. In selection of these zones, consideration was given to location and magnitude of the damage within each zone, tributaries flowing into the zone, and

hydraulic controls such as dams, bridges, falls, and constrictions. A control point, designated as the index station, was selected wherein the relationship between stage and discharge was characteristic of the entire zone. The damage zones with their geographical limits and selected index points are shown on Table 5. Stage-discharge curves and discharge-frequency curves (See Table 1) were prepared for all index points. In instances where the stage-discharge relationship for the index station was not characteristic of the entire zone, sub-zones were established and additional rating curves constructed for their control points. Stage-damage curves for the sub-zones were correlated with the index station by relating the stage-discharge curves.

15. Value of Flood Control Storage. - The approximate value of flood control storage was obtained for the principal tributaries in the Kennebec River Basin in order to provide a measure for the initial appraisal of flood control reservoirs. The monetary values of the storage were based on the following criteria and assumptions:

a. Six inches of storage is required to provide a reasonably high degree of control.

b. Optimum benefits are derived by considering individual control of the tributaries; that is, reservoirs on the tributaries would be acting alone, and not in combination with others.

c. Value of storage is derived for the total drainage area of the tributary, and any 10 square miles within the watershed of the tributary.

d. Except for areas with considerable variation in run-off characteristics, flood development is uniformly distributed through the entire watershed of the tributary.

16. The value of flood control storage for 10 square miles was computed to have data available to evaluate the effect of controlling small drainage areas, and to have a similar basis of comparison for all tributaries. Due to the curvature of the stage-damage relationship the unit value per acre-foot of storage varies with the magnitude of the reduction, which in turn varies with the size of the drainage area being controlled. Hence, the value of storage for total tributary watersheds are not directly comparable with each other.

17. The discharge reductions to be realized by controlling various tributaries were obtained from the routing computations of the TTCF which provides data on the individual contributions of each tributary to the peak flow at the damage centers. The reductions, expressed as percentages, were used to determine the applicable annual benefits, which were then used to obtain the annual benefits per acre-foot of storage on each tributary considered. The capital value of the storage was determined by using a 5 percent rate of amortization.

18. The value of flood control storage for 10 square miles and the total drainage area of the principal tributaries of the Kennebec River are as follows:

Tributary	Drainage Area Sq. Mi.	Value of Flood Control Storage in Dollars per Acre-Foot (1)	
		10 Sq.Mi.	Total D.A.
Kennebec R. above The Forks	320(2)	$10.50	$9.50
Dead R. at mouth	358(2)	15.10	11.80
Austin Str. at mouth	92	32.60	23.80
Carrabassett R. at mouth	395	16.10	13.20
Sandy R. at mouth	670	10.60	8.20
Sebasticook R. at mouth	970	1.90	1.50

(1) Assuming 6 inches of storage for applicable drainage area.
(2) Net drainage area.

The value of flood control storage for reservoirs controlling drainage areas between 10 square miles and the total watershed of the tributary may be obtained by interpolation.

19. The low value of flood control storage, as shown in the above tabulation, indicates that economic justification of flood control reservoirs in the Kennebec River Basin is very remote.

20. Plan of Development. - Projects considered in this study for the development of the Kennebec River Basin are:

a. Flood control reservoirs.

b. Power reservoirs.

c. Land treatment (Department of Agriculture).

21. The flood control and power reservoirs (See Plate 1) are as follows:

PROJECT	RIVER	DRAINAGE AREA SQ. MI.
Flood Control Reservoirs		
Anson	Carrabassett	341
Stark	Sandy	625
Power Projects (Plan "C-1")		
Moosehead Lake	Kennebec	1240
Indian Pond	"	1355
Cold Stream	"	1416
The Forks	"	2459
Flagstaff	Dead	520
Grand Falls	"	769 (gross) 249 (net)
Pierce Pond	Pierce Pond Stream	19
Greenleaf	Sandy	513

22. The existing Moosehead Lake already has a great modifying influence on all floods and, as the considered project would be similarly regulated, no additional flood control benefits would be attributable. Similarly, the present method of regulation of the new Flagstaff Reservoir modifies all floods flows on the upper Dead River. Indian Pond, Cold Stream and The Forks are run-of-river projects that will be maintained at, or near, full pool at all times for maximum power output, and hence will have little beneficial effect on reducing floods. In fact, due to loss of the natural valley storage, and decrease in the time of flood travel, these reservoirs will have to be regulated very judiciously in order to prevent a detrimental effect on downstream flood flows. Pierce Pond, a pumped storage regulating reservoir, will have no effect on floods.

23. The only projects in Plan "C-1" having significant flood control effectiveness are Grand Falls Reservoir on the Dead River and Greenleaf Reservoir on the Sandy River. The Grand Falls development is being considered for storage and regulation purposes and, as the project will be regulated in accordance with a prescribed rule curve, storage will be available for flood control on a seasonal basis. An important feature of this type of regulation is the fact that the reservoir will be drawn down in the early spring and thus will provide available storage for the spring floods. The Greenleaf development is also considered for storage and regulation purposes; however, due to the small amount of storage capacity in the reservoir, the flood control effectiveness is quite small. There is no definite allocation of storage for flood control purposes in either reservoir.

24. Although flood control reservoirs do not appear economically

feasible in the Kennebec River Basin (See paragraph 19), two such reservoirs were included in this study for demonstration purposes of hydraulic and economic analysis. The reservoirs, shown on Plate 1, are Anson Reservoir on the Carrabasset River with a drainage area of 341 square miles and storage capacity of 6.4 inches, and Stark Reservoir on the Sandy River with a drainage area of 625 square miles and 5.1 inches of storage capacity. Stark Reservoir was included to illustrate the allocation of benefits between two flood control reservoirs. In the comprehensive plan of development for the Kennebec River Basin, Greenleaf Reservoir located upstream of Stark is considered in lieu of the Stark flood control project.

25. Analysis of Flood Control Reservoirs. - For preliminary analysis it was assumed that the flood control reservoirs were 100 percent effective for the floods of record and the TTCF. This assumes that the storage is either sufficient to store the entire flood without any outflow, or that the method of regulation will effectively desynchronize all flood contributions from the watershed of the reservoir. The discharge reductions, applicable to the reservoirs, were obtained by routing the flood hydrographs at the dam sites to the downstream index points in accordance with paragraph 10 and deducting the routed component hydrographs from the total observed hydrographs. This method of analysis provides optimum effectiveness of the flood control projects, which in the future, may require some minor modifications when more detailed regulation procedures have been devised.

26. Flood Control Analysis of Power Reservoirs. - Due to the seasonal fluctuations in the available storage for control of floods, it was necessary to devise a method of analysis to determine the incidental monetary flood

control benefits of power projects. The principal items considered in determining the flood control effectiveness of this type of project are:

a. Monthly variation in available storage.

b. Natural valley storage in reservoir area.

c. Reservoir effectiveness with various amounts of storage.

d. Monthly variation in flood frequency.

27. With reference to Plates 4 and 5, the following is a step by step description of the method of flood control analysis of power reservoirs:

a. The rule curve for regulation of Grand Falls Reservoir (Chart A, Plate 4) was derived by the Power Section and is an envelope curve developed from analyzing periods of low flow to determine storage requirements which insure a prescribed minimum dependable flow.

b. The power storage available on the first day of each month for the twelve years studied is tabulated in Column A of Chart B. The difference between the total capacity of the reservoir and the power storage is the available flood control storage and is shown in Column B for each month. From this tabulation, the average, maximum, and minimum storage available for flood control was determined for the first day of each month.

c. A graphical presentation of the monthly available flood control storage in inches is shown on Chart C, Plate 4. The minimum storage curve was adopted for determination of relative flood control effectiveness because it represents the most dependable and conservative condition. The average minimum storage for each month is shown as a dashed bar-value. The natural valley storage in Grand Falls Reservoir was insignificant and therefore was omitted in the computations. In cases where the valley storage is significant the net effective flood control storage will be obtained by deducting the amount of valley storage from the gross available storage.

d. The flood control effectiveness of the reservoir for the various amounts of monthly storage was taken from the curves on Plate 5. The curves are empirical and are based on experience and judgment gained from past analysis of floods in New England rivers. It has been found that approximately 8 inches of storage is desirable for optimum control of floods resulting from rainfall and snowmelt in the spring months of March, April and May, while 6 inches of storage provides a high degree of protection during the remainder of the year. The slope, or curvature, of the lines between zero and 100 percent is problematical, but the assumed straight line relationship is considered reasonable.

28. The application of the preceding items is shown in the determination of the relative flood control effectiveness for Grand Falls Reservoir (Chart D, Plate 4) and is described as follows:

a. Line 1 lists the available flood control storage in inches for each month for Grand Falls Reservoir as determined from Chart C.

b. Line 2 gives the monthly flood control effectiveness in percent for the various amounts of storage as obtained from Plate 5.

c. Line 3 represents the flood potential indices for Maine river basins (See paragraph 6).

d. Line 4 shows the flood potential indices modified by Grand Falls Reservoir and are obtained by relating lines 2 and 3.

e. Line 5 indicates a relative flood control effectiveness of 46.4% for Grand Falls Reservoir and is the arithmetic difference of lines 3 and 4.

29. The relative flood control effectiveness is used to obtain the flood reductions applicable to the project. It is assumed that a reservoir having 100 percent effectiveness will provide complete control of the TTCF, viz; there will be no reservoir discharge during the flood. For Grand Falls Reservoir, the TTCF hydrograph at the reservoir was reduced 46.4 percent to obtain the reservoir outflow. This flow was then routed downstream to the damage centers to obtain the effective flood reductions. Further use of these data for economic analysis of the flood control effects of the power reservoirs is described in paragraph 37.

30. Greenleaf Reservoir on the Sandy River was similarly analyzed to determine the relative flood control effectiveness. Charts A, B and C, similar to those on Plate 4, are omitted in this summary, but the relative flood control effectiveness of Greenleaf Reservoir was determined to be 3.5% as shown on Plate 6. Although this effectiveness is practically negligible, it is included for further hydraulic and economic analysis.

31. It is recognized that the preceding method of analyzing the flood control effectiveness of power reservoirs is dependent on the correlation of several empirical relationships. There are many other variables that could be introduced into the problem, but it is difficult to properly evaluate these factors into simple mathematical terms. Such items to be considered are monthly flood volume frequencies, rules of reservoir regulation, and the effectiveness of the particular reservoir with the possibility that the floods may occur in a year when there is either more, or less, available flood control storage than existing under the assumed storage condition. It appears there is no precise solution to such a problem with so many complex and unrelated variables

but the method described herein correlates the major elements and appears to provide reasonable results.

32. Flood Control Analysis of the Land Treatment Program. - The effectiveness of the land treatment program proposed for the Kennebec River Basin has been determined by this office in collaboration with the Department of Agriculture. The TTCF hydrographs for tributaries and local ungaged areas were furnished to the Department of Agriculture for their use. The Department of Agriculture determined the effect of the land treatment program on these component hydrographs and furnished the data to this office. The modified component hydrographs were then combined and routed to determine the flood hydrographs at the damage centers on the main river. The effect of the land treatment program on the TTCF at selected points is shown on Table 4.

33. According to advice from the Department of Agriculture, the noted effectiveness of the land treatment program is an average value derived from studying floods in different seasons of the year, and, hence, is applicable for economic studies when used in conjunction with the TTCF. However, it is recognized by the Department of Agriculture that the percent reduction due to land treatment decreases with the larger floods. To allow for this variation, percent reductions for floods of various magnitudes were compared with the reduction obtained, (1) for a flood with a 50 percent chance of occurrence (i.e., a 2-year flood), and (2) for the TTCF. The resultant sets of ratios are called "relative effectiveness indices" as measured by the 2-year flood and the TTCF respectively. These relative effectiveness indices of the land treatment program for the Kennebec River Basin vary with flood magnitude, expressed in terms of frequency, approximately as follows:

PERCENT CHANCE OF OCCURRENCE	FREQUENCY IN YEARS	RELATIVE EFFECTIVENESS INDICES OF LAND TREATMENT PROGRAM AS MEASURED BY 2-YEAR FLOOD	AS MEASURED BY TTCF
50	2	1.00	1.10
20	5	0.95	1.04
10	10	0.92	1.01
6.6	15	0.91	1.00 (TTCF)
5	20	0.89	0.98
2	50	0.84	0.92
1	100	0.80	0.88
0.2	500	0.71	0.78
0.1	1000	0.67	0.74

34. The relative effectiveness indices of the land treatment program for the 2-year flood are similar in all river basins in northern New England. However, the relative magnitude of the TTCF, expressed in terms of frequency, may vary from basin to basin, hence, it should be noted that the relative effectiveness indices as measured by the TTCF listed above are applicable only in the Kennebec River Basin. On the basis of the arbitrary assignment of discharge values as discussed in paragraph 12, the TTCF has a frequency of approximately 15 years in the Kennebec River Basin.

35. The Damage Section in their economic analysis employ three frequency ranges. Based on the last column of the tabulation in paragraph 33, the average relative effectiveness indices of the land treatment program as measured by the TTCF for these three frequency ranges are:

DAMAGE FREQUENCY RANGES		AVERAGE RELATIVE EFFECTIVENESS INDICES OF LAND TREATMENT PROGRAM AS MEASURED BY TTCF
PERCENT CHANCE	YEARS	
100 to 5	1 to 20	1.00
5 to 1	20 to 100	0.94
1 to .05	100 to 2,000	0.80

The application of the average relative effectiveness indices listed above is described in paragraph 39.

36. Effect of Projects on Floods of Record. - Table 4 shows the effect of various projects on floods of record and the TTCF. In determining the flood control effectiveness of power reservoirs on past floods, it was necessary to know the amount of storage in the reservoirs available for flood control during the given month in which the flood occurred. However, in the absence of detailed storage analysis at Grand Falls Reservoir during the flood periods under consideration, it was assumed that the curve representing the average available flood control storage (Chart C, Plate 4) was applicable for the floods of March 1936 and November 1950. This resulted in a 100 percent flood control effectiveness for Grand Falls Reservoir for these two floods. The available storage in Greenleaf Reservoir during the same months shows a flood control effectiveness of 33% for an average month of March and 29% during November. Upon examination of the run-off from both the Sandy and Dead Rivers during the two peaked flood of March 1936, it was found that the volume of the first peak would have utilized the total storage capacity of Greenleaf, hence, the reservoir would have had no effect on the second and largest peak. The available storage at Grand Falls was sufficient to contain the total volume of run-off and remained 100% effective.

37. Economic Analysis. - The economic analysis of flood control and power reservoirs were measured entirely by the development of modified frequency curves that indicate the change in the probability of the flood's recurrence. The TTCF is used as the typical flood to determine the average effectiveness of the project within the basin. In general, the TTCF itself cannot be expressed in terms of frequency, or as having any definite chance of occurrence, for as noted in paragraph 12, the magnitude of the flood is only relative. However, the effect of proposed reservoir projects on the TTCF in terms of percentage reduction can be applied to all reasonable ranges of floods. Hence, the modified frequency curves are drawn with all discharges reduced in accordance with the percentage decrease determined by the effect of the project on the TTCF.

38. The effectiveness of the reservoirs was checked for a rare flood with a frequency of 2,000 years by increasing both the volume and peak of the TTCF. It was found that uncontrolled spillway discharge would occur at all reservoirs during the recession side of the flood hydrograph, but due to the flood hydraulics of the Kennebec River Basin the spillway discharge would not synchronize with the main river peaks. Hence, the reservoirs were equally effective in modifying the peaks of the large rare floods as they were for the floods of record. This computation substantiated the constant percent reduction applied to the natural frequency curve in order to determine the modified curve. This procedure, however, should be applied to each river basin to check the effectiveness of proposed reservoirs during the occurrence of a rare flood.

39. Based on the methods described in the preceding paragraphs, the reductions of all projects on the TTCF were determined acting alone and in vari-

ous combinations. Table 6 shows a complete tabulation of these data for use by the Damage Section to determine the annual flood control benefits attributable to the various projects. The following notes describe the use of these data for the economic analyses of assumed integrated basin programs and the allocation of benefits to the projects therein:

a. Columns 3, 4, 5 and 6 show the individual reductions of the four reservoirs considering each one acting alone.

b. Column 7 summarizes the discharge reductions provided by the land treatment program. The three sub-columns show the variation of the effectiveness in the three frequency ranges described in paragraph 35.

c. Columns 8, 9 and 10 show the reductions provided by the reservoirs in various combinations. The annual benefits to be allocated to each reservoir are proportional to the percentage reductions of each reservoir acting individually. It is noted that Stark Reservoir was studied for the academic purpose of allocation of benefits between two flood control reservoirs (Columns 6 and 8) and is replaced by Greenleaf Reservoir, also on the Sandy River, in the plan of development of the basin.

d. Columns 11 and 12 show the reductions obtained by the reservoirs and land treatment. The sub-divisions A, B and C indicate the effectiveness of the land treatment in the three frequency ranges. In allocation of the benefits to the projects, the reservoirs normally receive the initial benefits and the land treatment program is allocated the residual. For example, the allocation of benefits to the projects indicated in Column 12 at Madison is as follows:

(1) The reservoirs receive the <u>same</u> allocation of benefits

derived for a total reduction of 34.8 percent as shown in Column 10.

(2) The land treatment program receives the residual benefits or the difference between the total benefits and those allocated to the reservoirs.

e. It is assumed the above method of allocation is applicable only when the relative flood control effectiveness of a reservoir is more than twice the reduction obtained from land treatment over the drainage area above the reservoir. The relative effectiveness of Grand Falls is 46.4% as compared with 3.1% for land treatment and thus the benefits to the reservoir are allocated as described in the preceding paragraph. However, the relative effectiveness of Greenleaf Reservoir is only 3.5% (Plate 6) compared with a reduction of 6.8% applicable to land treatment on the watershed of Greenleaf Reservoir. For these conditions the following method of determining reductions and allocations was adopted.

(1) The TTCF inflow hydrograph at the reservoir was first reduced by land treatment and then further modified by the relative flood control effectiveness of the reservoir (3.5%). The modified TTCF hydrograph, reduced by both land treatment and the reservoir, was then routed downstream to determine the effective discharge reductions at the damage centers.

(2) The allocation of benefits to Greenleaf Reservoir and the land treatment was then determined in accordance with the procedure described in paragraph 39d.

40. This memorandum was prepared by E.F. Childs, Chief, Hydrology and Hydraulic Section with the assistance of J. Degen.

H. J. Kropper

H. J. KROPPER
Chief, Planning & Reports Branch

Atts. - 6 Tables & 6 Plates
(See next page)

Atts. - 6 Tables & 6 Plates

Table 1 - Tabulation of Frequency Curve Data

2 - Tributary Contributions to Floods of Record and the TTCF

3 - Lag-Average Reach Routing Coefficients

4 - Effect of Various Projects

5 - Description of Damage Zones - 4 sheets

6 - Discharge Reductions Provided by Various Projects

Plate 1 - Basin Map

2 - Typical Tributary Contribution Flood Hydrographs at Bingham and Waterville, Maine

3 - Flood Discharge Profiles and Tributary Contributions

4 - Relative Flood Control Effectiveness of Grand Falls Reservoir

5 - Flood Control Effectiveness of Power Reservoirs

6 - Relative Flood Control Effectiveness of Greenleaf Reservoir.

TABLE 1

TABULATION OF FREQUENCY CURVE DATA
FOR
DAMAGE ZONES

		ZONES							
		25	24	23	22B	22A	21	20	19
% Chance	Freq. In Years	Austin Str. at Bingham	Carrabassett at N. Anson	Sandy R. at Mercer	Sebasticook at Pittsfield	Sebasticook at mouth	Dead R. at The Forks	Kennebec Below The Forks	Kennebec at Bingham
.05	2,000	20,200	62,000	65,000	25,900	32,000	21,900	42,500	74,300
.10	1,000	17,500	55,000	59,000	23,400	28,800	20,400	39,600	69,100
.25	400	14,400	46,500	50,500	20,500	25,000	18,500	35,900	62,300
.50	200	12,300	40,500	44,200	18,500	22,300	17,200	33,400	57,100
1.00	100	10,500	35,400	38,900	16,600	20,000	15,800	30,700	52,500
1.25	80	10,000	33,900	37,200	16,200	19,400	15,500	30,100	51,400
1.50	66 2/3	9,600	32,900	35,900	15,800	19,000	15,100	29,300	50,300
2.0	50	8,800	30,300	33,800	15,000	17,800	14,600	28,300	48,100
3.0	33 1/3	8,000	27,800	30,900	14,000	16,700	13,700	26,600	45,300
4.0	25	7,400	25,900	29,000	13,200	15,800	13,100	25,400	43,300
5.0	20	6,900	24,500	27,400	12,600	15,000	12,700	24,600	41,800
10.0	10	5,600	20,400	23,000	10,900	13,000	11,300	21,900	37,300
20.0	5	4,400	16,400	18,700	9,200	11,100	10,000	19,400	32,600
30.0	3 1/3	3,700	14,200	16,300	8,200	9,900	9,200	17,800	29,700
40.0	2 1/2	3,200	12,700	14,400	7,400	9,000	8,500	16,500	27,600
50.0	2	2,800	11,700	13,000	6,800	8,200	8,100	15,700	26,200
60.0	1 2/3	2,500	11,000	12,000	6,300	7,600	7,700	14,900	25,000
70.0	1 7/16	2,300	10,300	11,400	5,800	7,000	7,400	14,400	24,100
80.0	1 1/4	2,100	9,800	11,000	5,600	6,600	7,100	13,800	23,200
90.0	1 1/8	2,000	9,300	10,500	5,300	6,400	6,800	13,200	22,500
95.0	1 1/16	1,900	9,000	10,300	5,200	6,200	6,600	12,800	22,100
99.0	1 1/64	1,800	8,600	10,100	5,000	6,000	6,400	12,400	21,500
99.9	1 +	1,700	8,400	10,000	4,900	5,800	6,300	12,200	21,200

17 & 18 15b&16b Kennebec at Madison	15a&16a Kennebec at Skowhegan	13 & 14 Kennebec at Shawmut	9 & 10 11 & 12 Kennebec at Waterville	7 & 8 Kennebec Below Sebasticook	5 & 6 3 & 4 1 & 2 Kennebec at Augusta
128,000	257,000	290,000	318,500	349,000	345,000
117,800	227,000	252,800	278,000	303,000	300,000
104,000	193,000	215,000	237,000	250,000	248,000
94,000	169,000	187,000	203,000	218,000	215,000
84,900	147,000	159,600	172,200	186,500	185,000
82,500	142,000	153,000	168,000	179,000	177,000
80,500	137,000	149,500	161,000	172,000	170,000
76,000	127,000	137,000	147,000	159,000	157,000
71,500	116,000	123,000	132,000	143,000	141,000
67,800	108,000	115,000	122,500	133,000	131,000
64,600	102,000	108,900	115,600	124,500	123,000
56,400	85,100	90,200	94,600	101,500	100,500
47,900	68,400	72,000	74,500	79,600	79,300
43,000	60,000	63,800	65,300	70,000	69,700
38,900	55,200	58,200	59,800	64,000	63,900
36,000	51,500	53,900	55,500	59,600	59,400
34,200	48,200	50,800	52,000	55,800	55,600
32,900	45,500	47,900	49,000	52,500	52,300
31,300	43,100	45,400	46,400	49,700	49,500
30,100	41,000	43,100	44,000	46,900	46,700
29,500	39,700	41,700	42,600	45,400	45,200
28,600	38,500	40,200	41,000	43,800	43,600
28,000	37,800	39,700	40,500	43,000	42,900

TABLE 1

TABLE 2

KENNEBEC RIVER BASIN

TRIBUTARY CONTRIBUTIONS TO FLOODS OF RECORD
AND THE
TYPICAL TRIBUTARY CONTRIBUTION FLOOD

LOCATION	CONTRIBUTING COMPONENT	D.A. SQ.MI.	D.A. %	MARCH 1936 DISCHARGE	MARCH 1936 %	NOVEMBER 1950 DISCHARGE	NOVEMBER 1950 %	APRIL 1951 DISCHARGE	APRIL 1951 %	T.T.C.F. DISCHARGE	T.T.C.F. %
The Forks	Kennebec R.	320*	26.6	16,500	38.8	7,500	30.8	6,500	35.1	10,000	44.6
	Dead R.	878	73.4	26,000	61.2	16,800	69.2	12,000	64.9	12,400	55.4
		1,198	100.0	42,500	100.0	24,300	100.0	18,500	100.0	22,400	100.0
Bingham	Kennebec R.	320*	22.0	16,500	28.2	7,200	25.2	4,800	22.0	9,700	27.2
	Dead R.	878	60.4	22,500	38.5	9,000	31.4	5,200	23.9	12,400	34.8
	Local Area	162	11.2	15,000	25.6	6,600	23.1	7,300	33.5	8,000	22.5
	Austin Str.	92	6.4	4,500	7.7	5,800	20.3	4,500	20.6	5,500	15.5
		1,452	100.0	58,500	100.0	28,600	100.0	21,800	100.0	35,600	100.0
Madison	Kennebec R.	320*	16.6	12,900	16.4	6,200	12.4	4,000	9.8	8,300	14.2
	Dead R.	878	45.5	13,100	16.6	7,300	14.6	4,300	10.6	10,900	18.6
	Local Area	162	8.4	11,200	14.2	7,700	15.4	6,500	16.0	8,700	14.8
	Austin Str.	92	4.8	5,800	7.3	5,200	10.4	3,900	9.6	5,200	8.9
	Local Area	80	4.2	5,000	6.3	7,800	15.6	3,700	9.1	5,300	9.0
	Carrabassett R.	395	20.5	31,000	39.2	15,800	31.6	18,300	44.9	20,200	34.5
		1,927	100.0	79,000	100.0	50,000	100.0	40,700	100.0	58,600	100.0
Skowhegan	Kennebec R.	320*	11.9	12,200	9.1	6,000	8.6	4,000	6.0	8,300	9.1
	Dead R.	878	32.6	13,300	10.0	7,300	10.4	4,200	6.3	10,900	12.0
	Local Area	162	6.0	12,000	9.0	7,800	11.1	6,200	9.3	8,700	9.5
	Austin Str.	92	3.4	4,500	3.4	5,000	7.2	3,800	5.6	5,200	5.7
	Local Area	80	3.0	5,000	3.8	7,900	11.3	3,500	5.3	5,200	5.7
	Carrabassett R.	395	14.7	30,500	22.8	15,300	21.9	17,600	26.6	19,600	21.5
	Sandy R.	670	24.9	46,500	34.8	18,000	25.6	24,500	37.0	28,900	31.8
	Local Area	95	3.5	9,500	7.1	2,700	3.9	2,600	3.9	4,300	4.7
		2,692	100.0	133,500	100.0	70,000	100.0	66,400	100.0	91,100	100.0
Waterville	Kennebec R.	320*	10.9	11,500	7.6	5,800	7.7	3,800	5.2	8,000	8.0
	Dead R.	878	29.9	12,700	8.4	6,900	9.2	4,200	5.8	10,900	10.9
	Local Area	162	5.5	11,400	7.6	7,500	10.0	5,700	7.9	6,500	6.5
	Austin Str.	92	3.1	5,000	3.3	5,000	6.7	3,800	5.2	4,900	4.9
	Local Area	80	2.7	5,000	3.3	7,600	10.1	3,500	4.8	5,100	5.1
	Carrabassett R.	395	13.4	29,600	19.6	14,500	19.4	16,900	23.3	18,200	18.2
	Sandy R.	670	22.8	44,800	29.7	17,700	23.6	23,600	32.6	27,500	27.5
	Local Area	95	3.2	8,600	5.7	3,400	4.5	2,300	3.2	4,000	4.0
	Local Area	250	8.5	22,400	14.8	6,600	8.8	8,700	12.0	14,900	14.9
		2,942	100.0	151,000	100.0	75,000	100.0	72,500	100.0	100,000	100.0
Augusta	Kennebec R.	320*	7.6	11,000	6.9	5,700	7.1	3,800	4.6	7,600	7.0
	Dead R.	878	20.8	12,000	7.5	6,800	8.5	3,600	4.4	10,400	9.6
	Local Area	162	3.9	10,500	6.6	7,400	9.3	5,500	6.7	6,200	5.7
	Austin Str.	92	2.2	4,600	2.9	4,900	6.1	3,500	4.3	4,700	4.3
	Local Area	80	1.9	4,300	2.7	7,400	9.3	3,300	4.0	4,900	4.5
	Carrabassett R.	395	9.4	28,600	17.9	14,500	18.1	16,000	19.5	17,400	16.0
	Sandy R.	670	15.9	41,800	26.1	17,200	21.5	22,100	27.0	26,300	24.2
	Local Area	95	2.3	8,200	5.1	2,200	2.8	1,700	2.1	3,800	3.5
	Local Area	250	5.9	22,000	13.7	7,600	9.5	8,300	10.1	14,100	13.0
	Sebasticook R.	970	23.0	15,000	9.4	4,800	6.0	10,200	12.4	9,200	8.5
	Local Area	300	7.1	2,000	1.2	1,500	1.8	4,000	4.9	4,000	3.7
		4,212	100.0	160,000	100.0	80,000	100.0	82,000	100.0	108,600	100.0

* NOTE - Net drainage area = 320 sq.mi. Gross drainage area, including area above Moosehead Lake, = 1,570 sq.mi.

TABLE 3

KENNEBEC RIVER BASIN

LAG-AVERAGE REACH ROUTING COEFFICIENTS

Routing Reach No.	Reach Limits: R.M.	Reach Limits: Description	Coefficients: Average (in no. of Periods)	Coefficients: Lag (in no. of periods from middle of average)
	140.4	The Forks (U.S.G.S. Gage)		
1			0	0
	117.5	Bingham (U.S.G.S. Gage)		
2			3	2
	101.1	Mouth of Carrabassett R.		
3			5	1
	93.0	Mouth of Sandy R.		
4			5	2
	81.4	Skowhegan (Weston Dam)		
5			9	2
	62.5	Waterville Hollingsworth & Whitney Paper Co. Dam		
6			9	1
	43.5	Augusta Weather Bureau Gage		

NOTES:

1. These routing coefficients are applicable only for instantaneous flows expressed in c.f.s. for 2-hour intervals of time.

2. Lag-Average coefficients are normally expressed as AVERAGE/LAG - n hour c.f.s.

   Example. 5/1 - two hour c.f.s. denotes an Average of five instantaneous 2-hour c.f.s. and a Lag of one 2-hour period.

TABLE 4

EFFECT OF VARIOUS PROJECTS

Projects(a)	March 1936			November 1950			T.T.C.F.		
	Natural Peak C.F.S.	Reduced Peak C.F.S.	Reduction %	Natural Peak C.F.S.	Reduced Peak C.F.S.	Reduction %	Natural Peak C.F.S.	Reduced Peak C.F.S.	Reduction %
BINGHAM D.A. 2710 Sq.Mi.									
G.F.	57,800	40,400(b)	30.1	28,600	22,230	20.9	35,600	31,600	11.2
L	57,800	(c)	--	28,600	(c)	--	35,600	34,900	2.0
G.F. and L	57,800	(c)	--	28,600	(c)	--	35,600	31,200	12.4
MADISON D.A. 3210 Sq.Mi.									
G.F.	79,000	67,900(b)	14.1	50,000	43,870	12.3	58,600	55,100	6.0
A	79,000	62,400	20.4	50,000	36,970	26.1	58,600	42,000	28.3
L	79,000	(c)	--	50,000	(c)	--	58,600	57,800	1.4
G.F. and A	79,000	45,000(b)	43.0	50,000	31,400	37.2	58,600	38,200	34.8
G.F.,A and L	79,000	(c)	--	50,000	(c)	--	58,600	37,550	35.9
WATERVILLE D.A. 4200 Sq.Mi.									
G.F.	151,000	138,000(b)	8.6	75,000	70,020	6.6	100,000	97,000	3.0
A	151,000	126,000	16.6	75,000	62,300	16.9	100,000	83,300	16.7
G	151,000	151,000	0	75,000	70,750	5.7	100,000	99,400	0.6
L	151,000	(c)	--	75,000	(c)	--	100,000	97,290	2.7
G.F.,A and G	151,000	115,300(b)	23.6	75,000	53,350	28.9	100,000	79,400	20.6
G.F.,A,G and L	151,000	(c)	--	75,000	(c)	--	100,000	76,800	23.2

(a) Projects

Revised - December 2, 1953

- G.F. Grand Falls Res. (Power Reservoir on Dead River)
- G Greenleaf Res. (Power Reservoir on Sandy River)
- A Anson Res. (Flood Control Res. on Carrabassett River)
- L Land Treatment Program

(b) Data reflects reductions due to Flagstaff and Grand Falls Reservoirs of which 60% is credited to Flagstaff Reservoir and 40% is credited to Grand Falls Reservoir.

(c) Data are not available.

TABLE 5

DESCRIPTION OF DAMAGE ZONES

ZONE NO.	RIVER	DESCRIPTION OF ZONE	INDEX STATION
1	Kennebec	Left Bank - Richmond-Dresden Bridge to Dresden-Pittston Line.	Mile 27± (Richmond)
2	"	Right Bank - Below Richmond-Gardiner Town Line.	Mile 27± (Richmond)
3	"	Left Bank - Dresden-Pittston Line to Point opposite Farmingdale-Hallowell Line.	Bridge - State Hwy. #226 (Gardiner)
4	"	Right Bank - Richmond-Gardiner Line to Farmingdale-Hallowell Line.	Bridge - State Hwy. #226 (Gardiner)
5	"	Left Bank - Point opposite Farmingdale-Hallowell Line to Augusta Dam.	U.S.W.B. Gage, Mile 43± (Augusta)
6	"	Farmingdale-Hallowell Line to Augusta Dam.	U.S.W.B. Gage, Mile 43± (Augusta)
7	"	Left Bank - Augusta Dam to Lockwood Dam.	Mouth of Sebasticook R. - Mile 61±
8	"	Right Bank - Augusta Dam to Lockwood Dam.	Mouth of Sebasticook R. - Mile 61±
9	"	Left Bank - Lockwood Dam to Hollingsworth-Whitney Dam, Winslow.	Tailwater - H&W Paper Co. Dam (Waterville)
10	"	Right Bank - Lockwood Dam to Hollingsworth-Whitney Dam, Waterville.	Tailwater - H&W Paper Co. Dam (Waterville)
11	"	Left Bank - Hollingsworth-Whitney Dam at Winslow to Central Maine Power Co. Dam at Shawmut.	Bridge - State Hwy. #11 (Fairfield)

TABLE 5 (Cont'd)

DESCRIPTION OF DAMAGE ZONES

ZONE NO.	RIVER	DESCRIPTION OF ZONE	INDEX STATION
12	Kennebec	Right Bank - Hollingsworth-Whitney Dam at Waterville to Central Maine Power Co. Dam at Shawmut.	Bridge - State Hwy. #11 (Fairfield)
13	"	Left Bank - Central Maine Power Co. Dam at Shawmut to Weston Dam at Skowhegan.	Bridge - State Hwy. #24 (Mile 73±)
14	"	Right Bank - Central Maine Power Co. Dam at Shawmut to Weston Dam at Skowhegan.	Bridge - State Hwy. #24 (Mile 73±)
15A	"	Left Bank - Weston Dam at Skowhegan to Mouth of Sandy River.	Mile 86± (Norridge-wock)
16A	"	Right Bank - Weston Dam at Skowhegan to Mouth of Sandy River.	Mile 86± (Norridge-wock)
15B	"	Left Bank - Mouth of Sandy River to Great Northern Paper Co. Dam at Madison.	Tailwater - Great Northern Paper Co. Dam (Madison)
16B	"	Right Bank - Mouth of Sandy River to Great Northern Paper Co. Dam at Madison.	Tailwater - Great Northern Paper Co. Dam (Madison)
17	"	Left Bank - Great Northern Paper Co. Dam at Madison to Williams Station Dam at Solon.	Mile 96.0 (Madison)
18	"	Right Bank - Great Northern Paper Co. Dam at Madison to Williams Station Dam at Solon.	Mile 96.0 (Madison)
19	"	Williams Station Dam at Solon to Wyman Dam at Bingham.	U.S.G.S.Gage(Bingham)

TABLE 5 (Cont'd)

DESCRIPTION OF DAMAGE ZONES

ZONE NO.	RIVER	DESCRIPTION OF ZONE	INDEX STATION
20	Kennebec	Wyman Dam at Bingham to The Forks.	Wyman Dam (Headwater)
21	Dead	Above The Forks.	U.S.G.S.Gage (The Forks)
22A	Sebasticook	Fort Halifax Dam to Waldo-Somerset Co. Line.	Bridge - Mile 72± (Clinton)
22B	"	Above Waldo-Somerset Co. Line.	U.S.G.S.Gage(Pittsfield)
23A	Sandy	Mouth to Madison Elec. Co. Dam (Part of Reach 16A).	(Same as 16A)
23B	"	Madison Elec. Co. Dam to U.S. Route 2 Bridge at New Sharon.	U.S.G.S.Gage (Nr. Mercer)
23C	"	U.S. Route 2 Bridge at New Sharon to Farmington Falls Dam.	Mile 111.5
23D	"	Farmington Falls Dam to Farmington.	Mile 121.9
24A	Carrabassett	Kennebec River to former North Anson Dam. (Part of Reach 18).	(Same as 18)
24B	"	Former Anson Dam to former Franklin Power Co. Dam.	U.S.G.S.Gage (N.Anson)
24C	"	Former Franklin Power Co. Dam to East New Portland Dam.	U.S.G.S.Gage (N.Anson)
24D	"	East New Portland Dam to New Portland Suspension Bridge.	U.S.G.S.Gage (N.Anson)
24E	"	New Portland Suspension Bridge to Kingfield.	U.S.G.S.Gage (N.Anson)
25	Austin Str.	Mouth to U.S.G.S.Gage above Highway Bridge.	U.S.G.S.Gage (Bingham)

TABLE 5 (Cont'd)

TABLE 6

DISCHARGE REDUCTIONS EXPRESSED IN PERCENT PROVIDED BY VARIOUS PROJECTS AS MEASURED BY THE TYPICAL TRIBUTARY CONTRIBUTION FLOOD

1	2	3	4	5	6	7			8	9	10	11			12		
		PROJECTS (a)															
LOCATION	DAMAGE ZONE	G.F. %	G %	A %	S %(d)	L %(b)			A & S %(d)	G.F. & G %	G.F.,G & A %	G.F.,G & L %(b)			G.F.,G,A&L %(b)		
						A	B	C				A	B	C	A	B	C
Kennebec River																	
Bingham	19	11.2	0	0	0	1.6	1.9	2.0	0	11.2	11.2	12.2	12.3	12.4	12.2	12.3	12.4
Madison	17&18, 15b&16b	6.0	0	28.3	0	1.1	1.3	1.4	28.3	6.0	34.8	6.7	6.9	7.0	35.6	35.8	35.9
Skowhegan	15a & 16a	3.7	0.8	17.9	29.9	2.3	2.7	2.9	47.6	4.7	22.8	6.9	7.3	7.5	24.6	24.9	25.1
Shawmut	13 & 14	3.2	0.7	17.0	25.6	2.4	2.8	3.0	42.4	4.0	21.1	6.3	6.7	6.9	23.4	23.8	24.0
Waterville	11&12, 9&10	3.0	0.6	16.7	24.0	2.2	2.5	2.7	40.5	3.8	20.6	5.8	6.3	6.5	22.7	23.0	23.2
Below Sebasticook R.	7 & 8	2.8	0.6	15.7	22.0	2.2	2.5	2.7	37.5	3.5	19.2	5.5	6.0	6.2	21.4	21.7	21.9
Augusta	5&6, 3&4, 1&2	2.8	0.6	14.5	21.4	2.1	2.4	2.6	35.7	3.5	18.0	5.4	5.7	5.9	20.1	20.4	20.6
Tributaries																	
Dead River	21	32.3	0	0	0	2.5	2.9	3.1	0	32.3	32.3	32.5	32.6	32.7	32.5	32.6	32.7
Austin Stream	25	0	0	0	0	4.6	5.5	5.8	0	0	0	4.6	5.5	5.8	4.6	5.5	5.8
Carrabassett R.	24b,24c,24d,&24e	0	0	(c)	0	4.0	4.7	5.0	(c)	0	(c)	4.0	4.7	5.0	4.0	4.7	5.0
Sandy R.	23b, 23c, 23d	0	(c)	0	(c)	5.4	6.4	6.8	(c)	(c)	(c)	5.4	6.4	6.8	5.4	6.4	6.8
Sebasticook R.	22a & 22b	0	0	0	0	4.3	5.1	5.4	0	0	0	4.3	5.1	5.4	4.3	5.1	5.4

(a) Projects

G.F. Grand Falls Res. (Power Reservoir on Dead River)
G Greenleaf Res. (Power Reservoir on Sandy River)
A Anson Res. (Flood Control Reservoir on Carrabassett River)
S Stark Res. (Flood Control Reservoir on Sandy River)
L Land Treatment Program

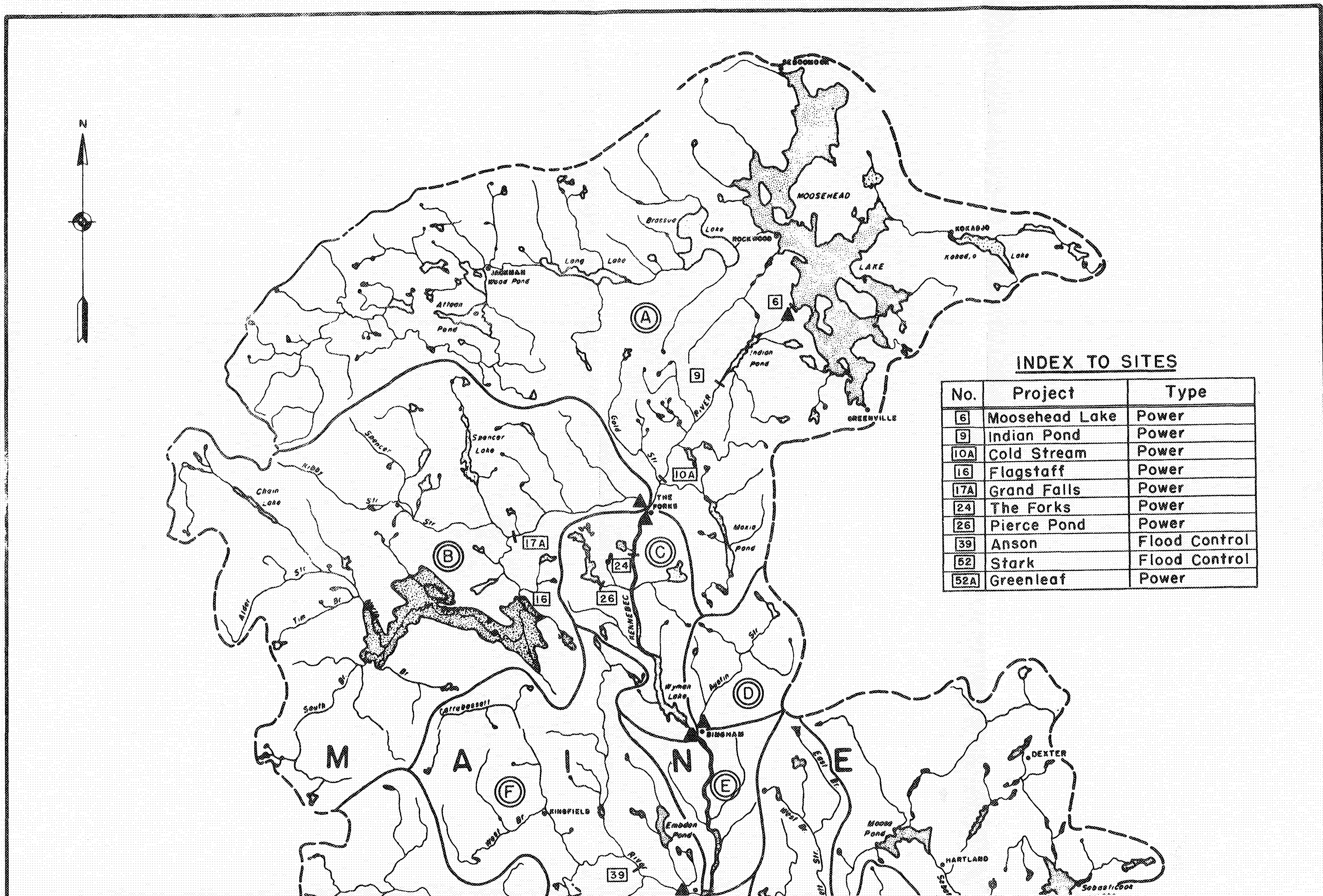
(b) Frequency Ranges

A - 2,000 to 100 years
B - 100 to 20 years
C - 20 to 1 years

(c) Damage zones are located in or upstream from the reservoir area.

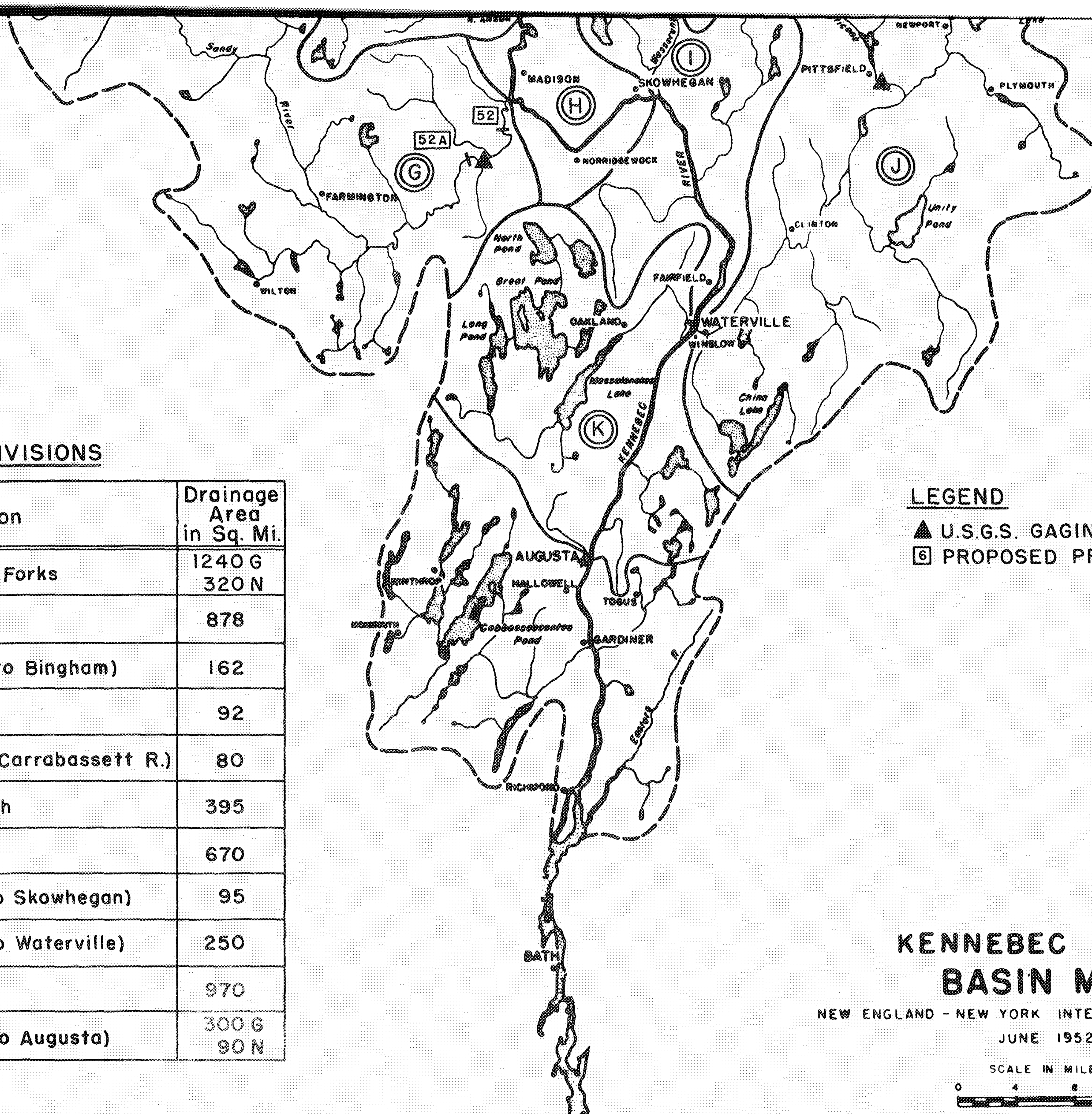
(d) Stark Reservoir was studied for academic purposes only to demonstrate allocations between flood control reservoirs. Greenleaf Reservoir, located upstream of Stark Reservoir, is included in the recommended plan of development of the Kennebec River Basin.

Revised - December 2, 1953



INDEX TO SITES

No.	Project	Type
6	Moosehead Lake	Power
9	Indian Pond	Power
10A	Cold Stream	Power
16	Flagstaff	Power
17A	Grand Falls	Power
24	The Forks	Power
26	Pierce Pond	Power
39	Anson	Flood Control
52	Stark	Flood Control
52A	Greenleaf	Power



BASIN SUB-DIVISIONS

Area	Description	Drainage Area in Sq. Mi.
A	Kennebec R. above The Forks	1240 G 320 N
B	Dead R. at mouth	878
C	Local area (The Forks to Bingham)	162
D	Austin Str. at mouth	92
E	Local area (Bingham to Carrabassett R.)	80
F	Carrabassett R. at mouth	395
G	Sandy R. at mouth	670
H	Local area (Carrab. R. to Skowhegan)	95
I	Local area (Skowhegan to Waterville)	250
J	Sebasticook R. at mouth	970
K	Local area (Waterville to Augusta)	300 G 90 N

LEGEND

▲ U.S.G.S. GAGING STATIONS

6 PROPOSED PROJECTS

KENNEBEC RIVER BASIN MAP

NEW ENGLAND - NEW YORK INTER-AGENCY COMMITTEE

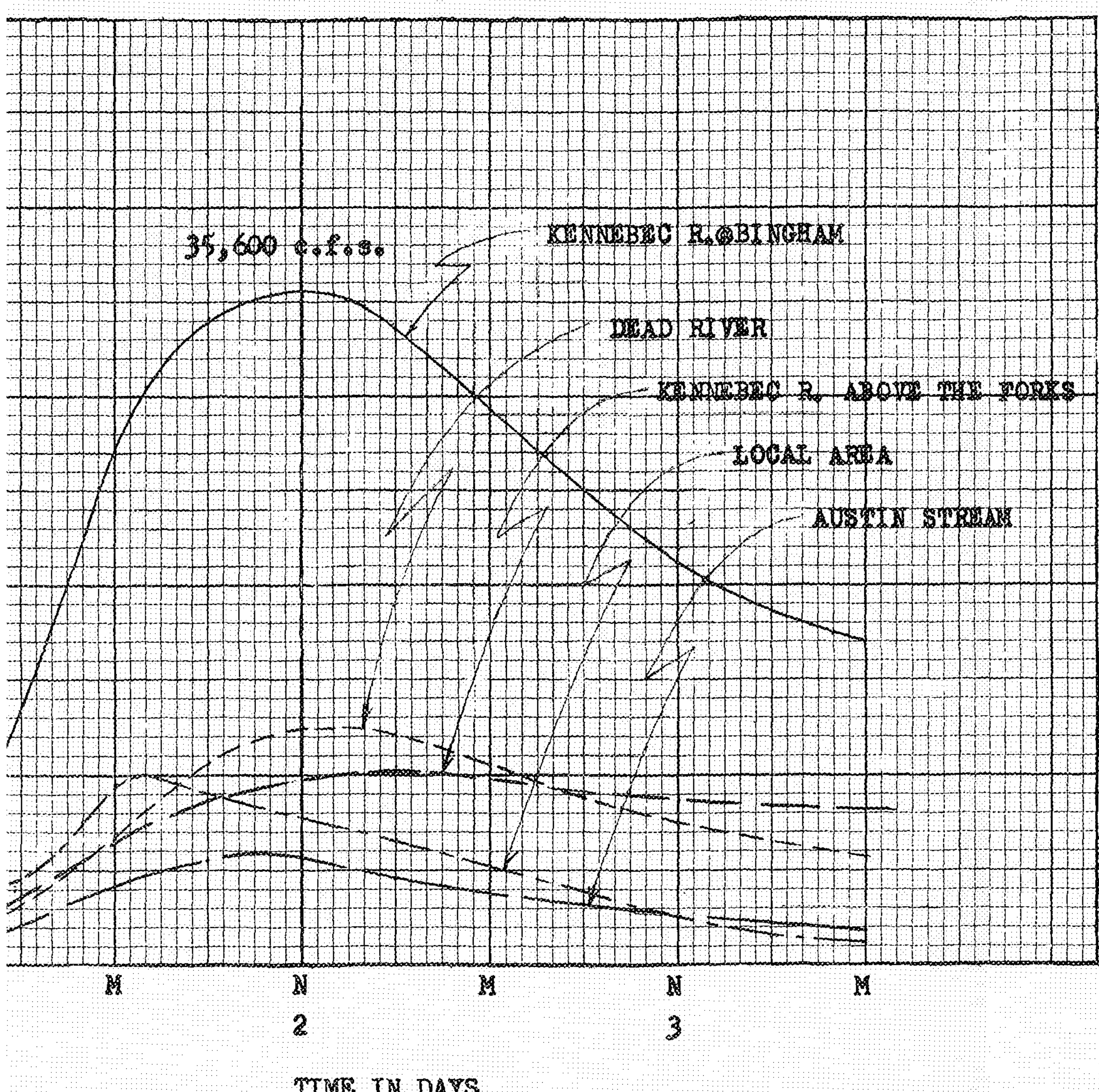
JUNE 1952

SCALE IN MILES

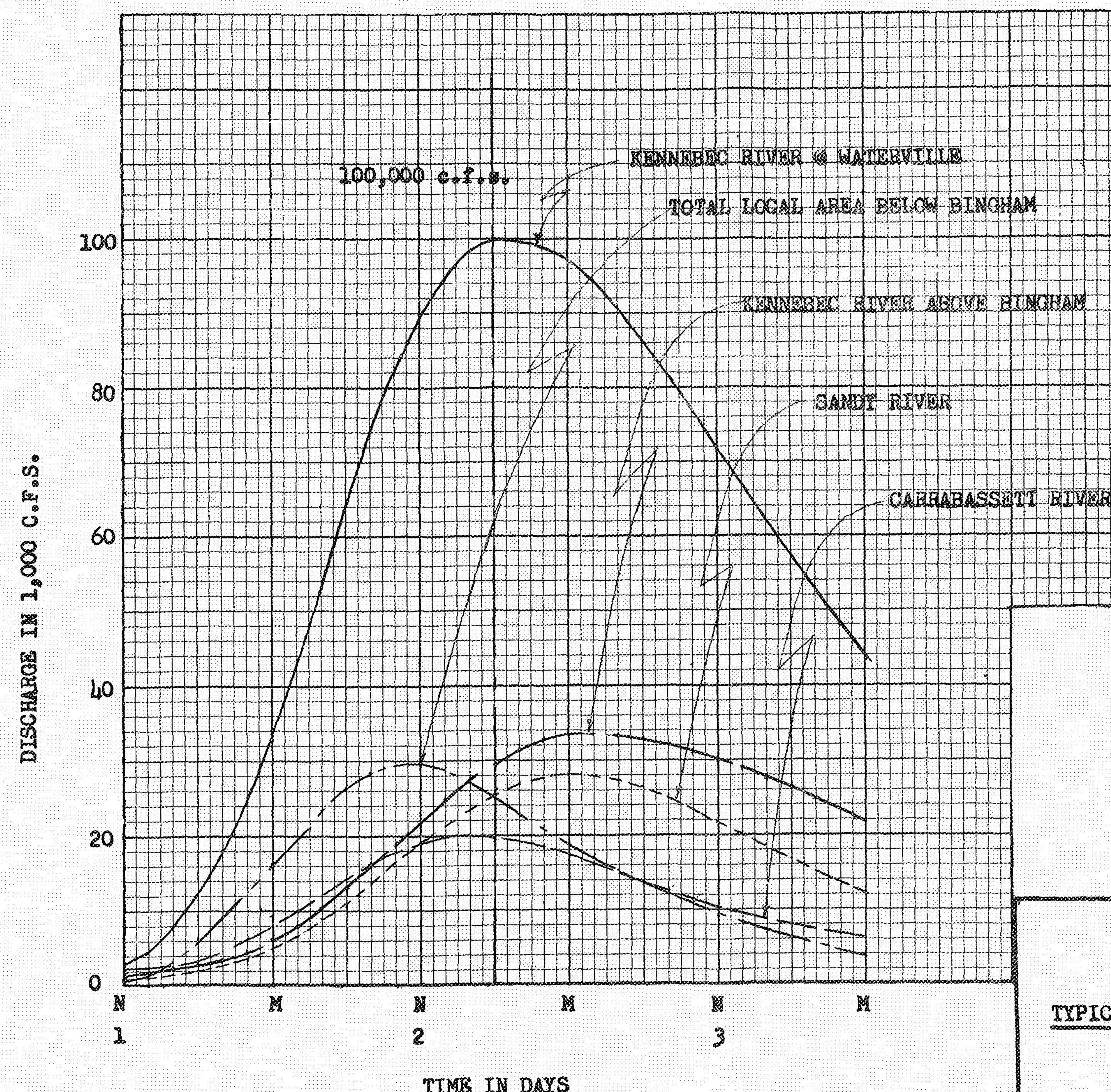
0 4 8 12

ARMY NED BOSTON JUNE 1, 1952

BINGHAM, MAINE



WATERVILLE, MAINE

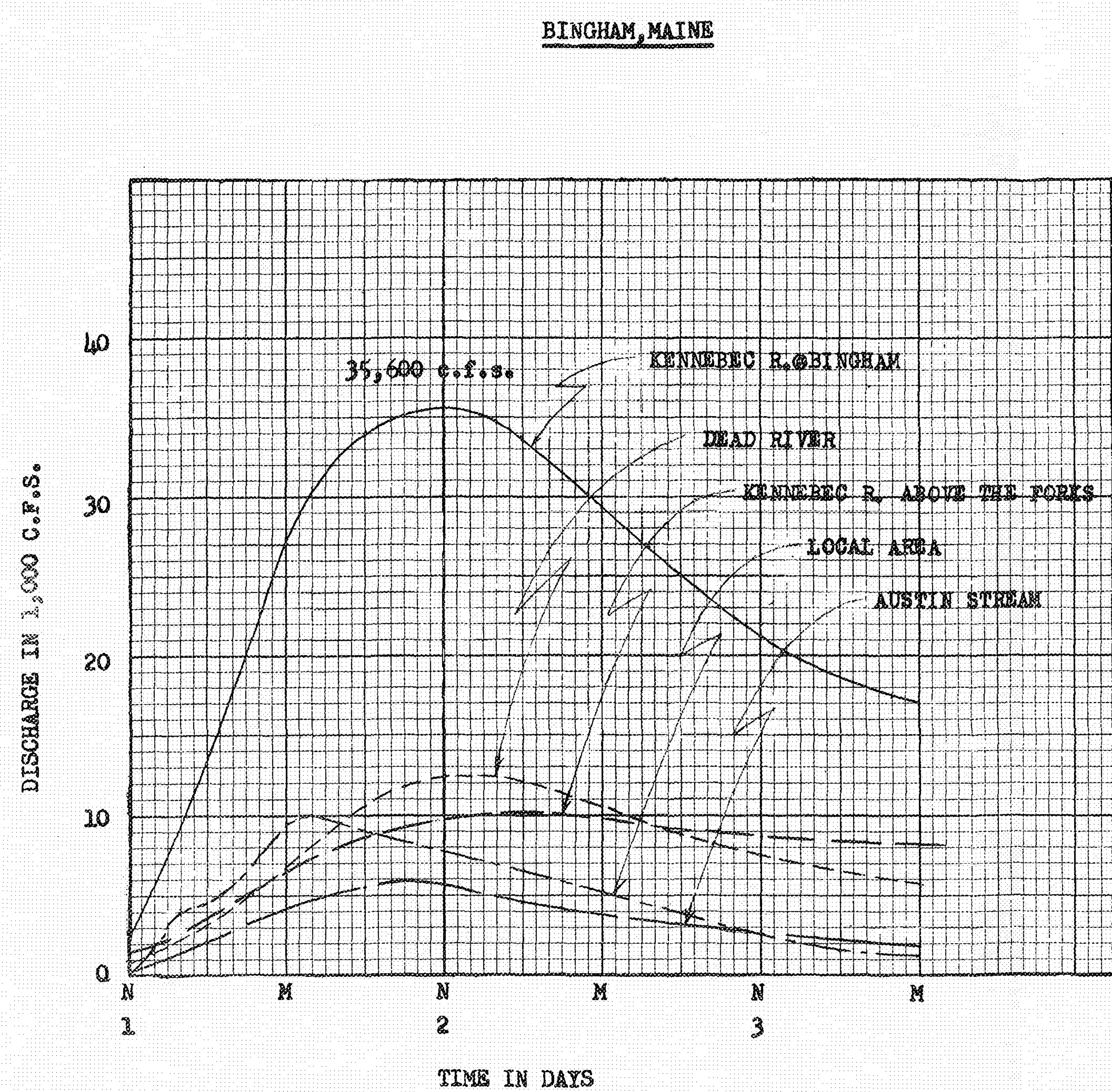


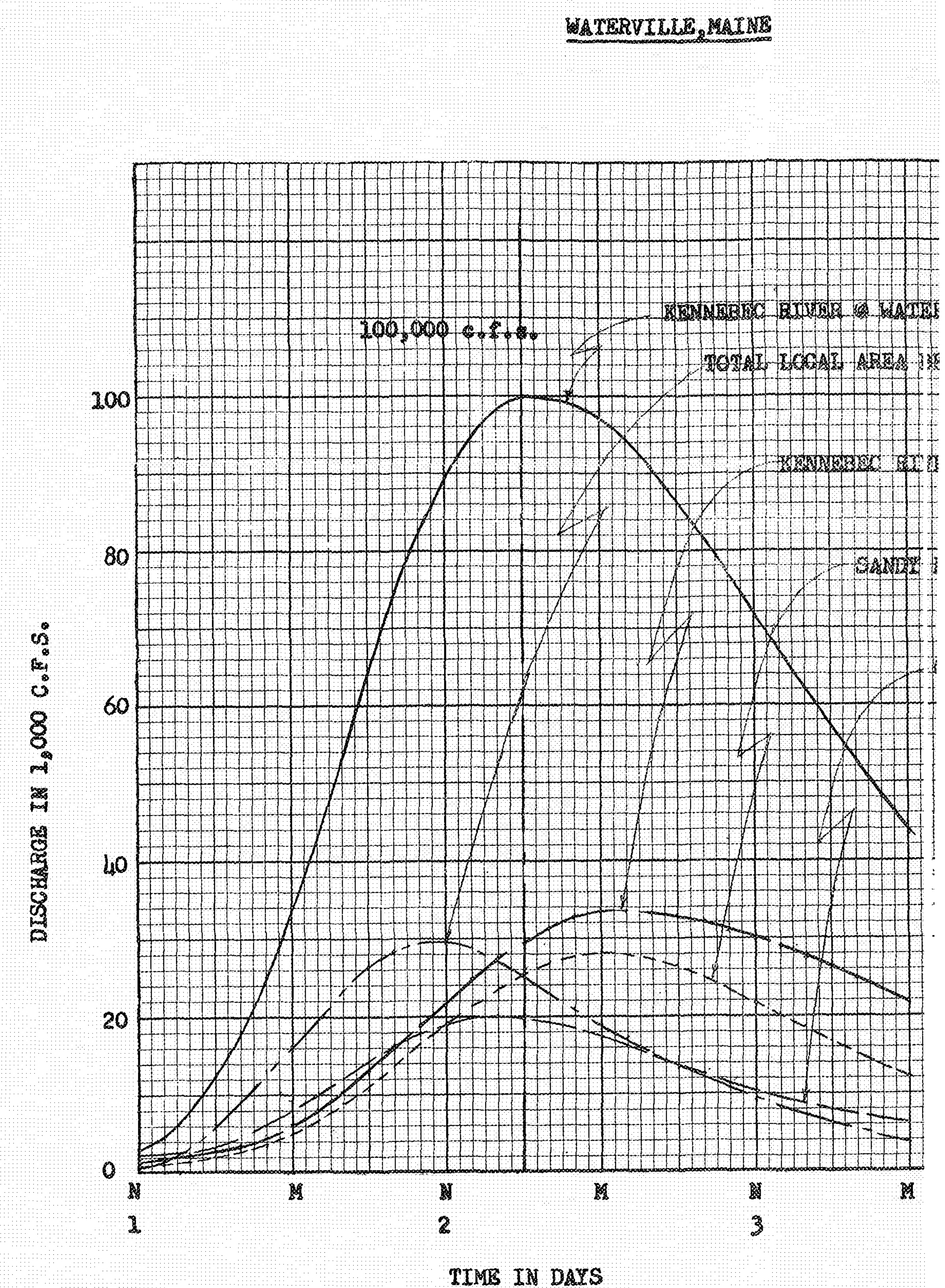
KENNEBEC RIVER BASIN

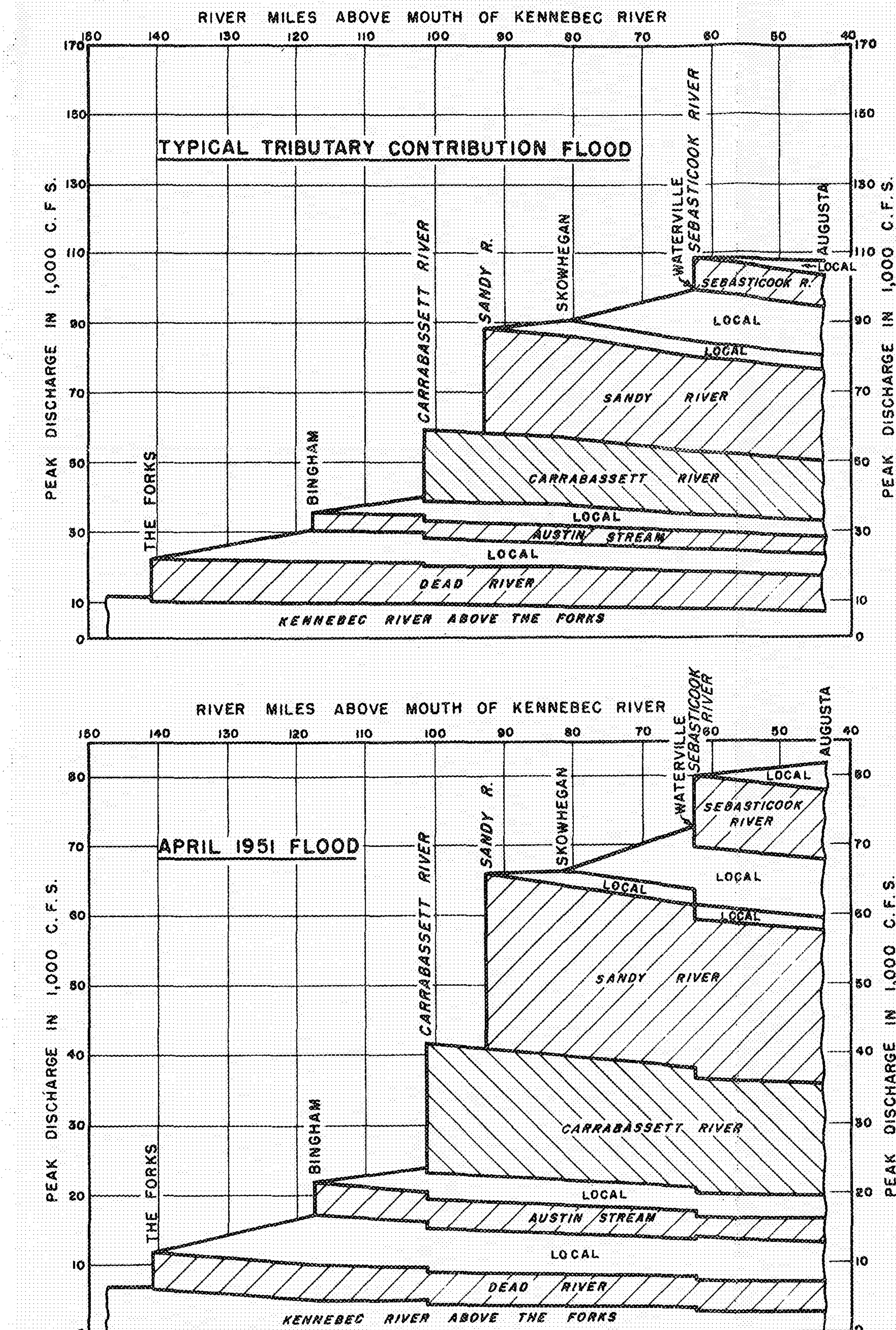
TYPICAL TRIBUTARY CONTRIBUTION FLOOD HYDROGRAPHS

AT

BINGHAM and WATERVILLE, MAINE


BINGHAM, MAINE
35,600 c.f.s.
KENNEBEC R.@BINGHAM
DEAD RIVER
KENNEBEC R. ABOVE THE FORKS
LOCAL AREA
AUSTIN STREAM
DISCHARGE IN 1,000 C.F.S.
TIME IN DAYS


WATERVILLE, MAINE
100,000 c.f.s.
DISCHARGE IN 1,000 C.F.S.
TIME IN DAYS



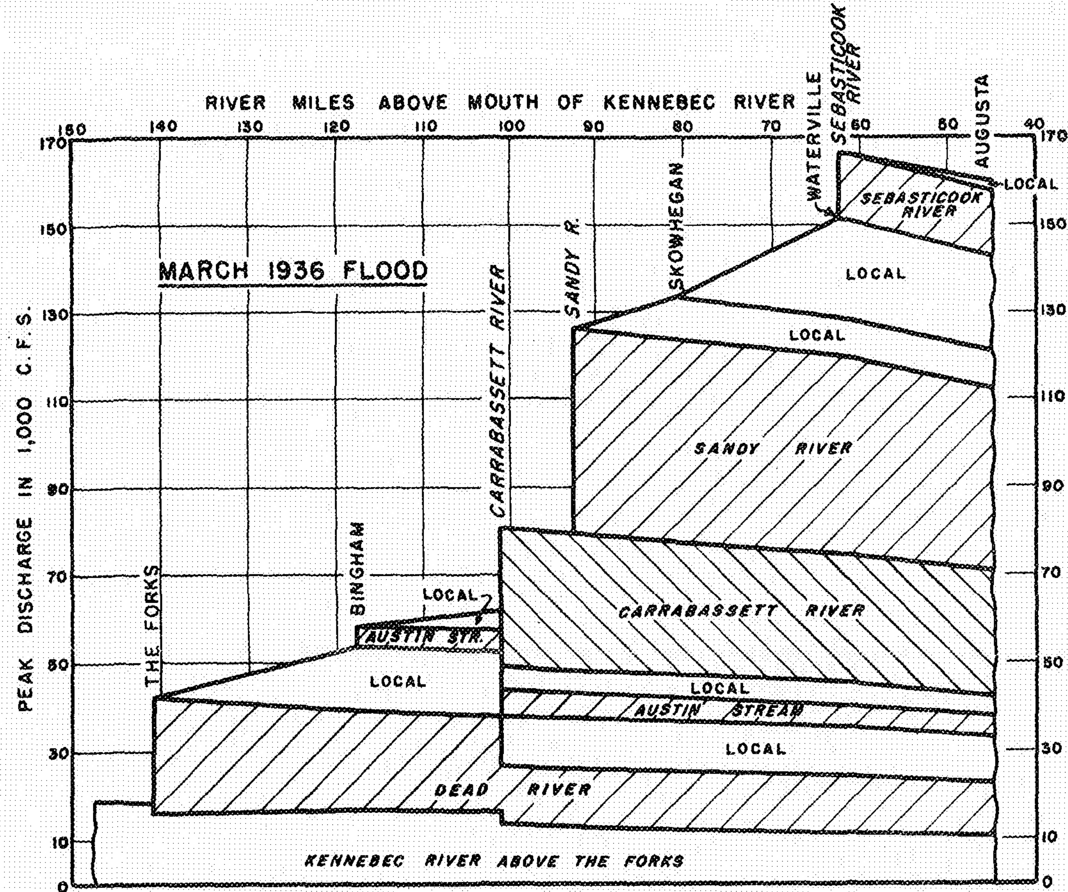
NOTE
TYPICAL TRIBUTARY CONTRIBUTION FLOOD REFLECTS THE OPERATION OF FLAGSTAFF RESERVOIR ON THE DEAD RIVER.

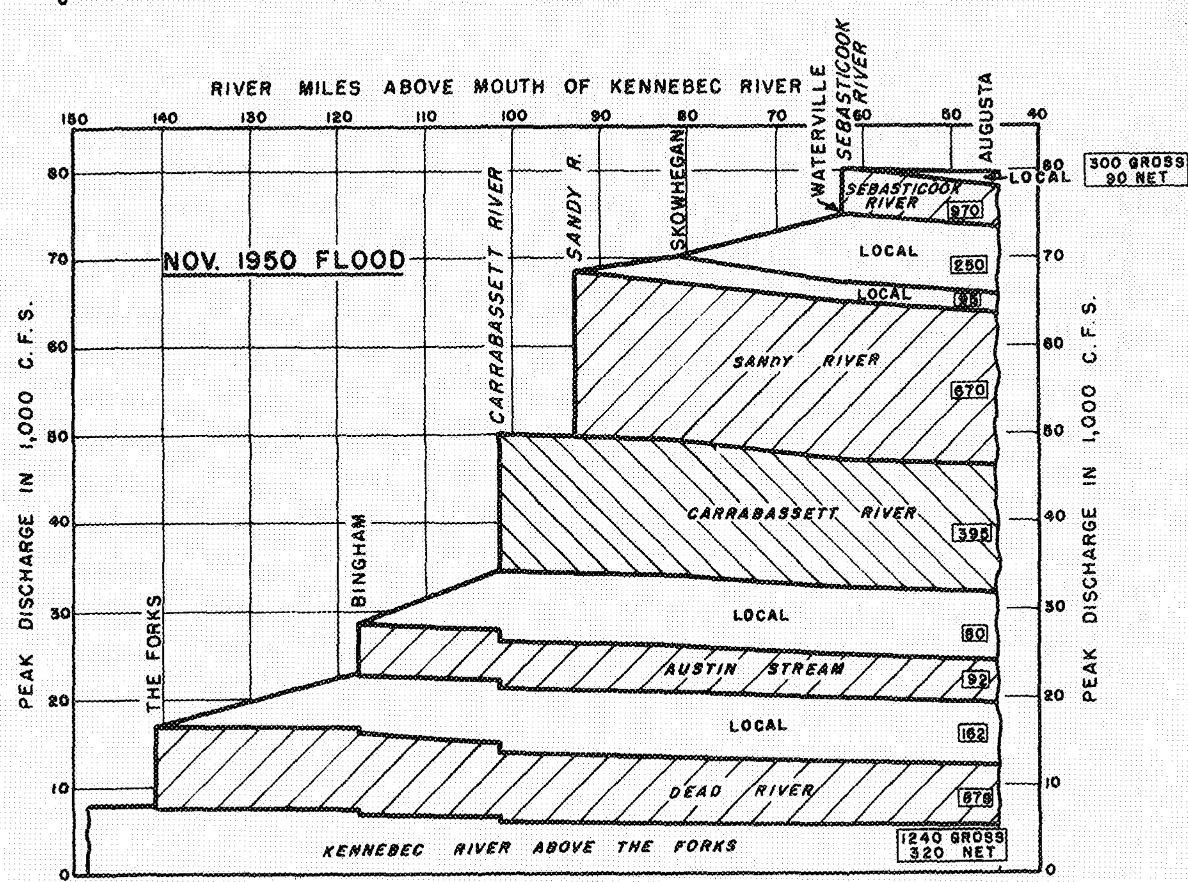
LEGEND
670 DRAINAGE AREA IN SQUARE MILES.

KENNEBEC RIVER BASIN

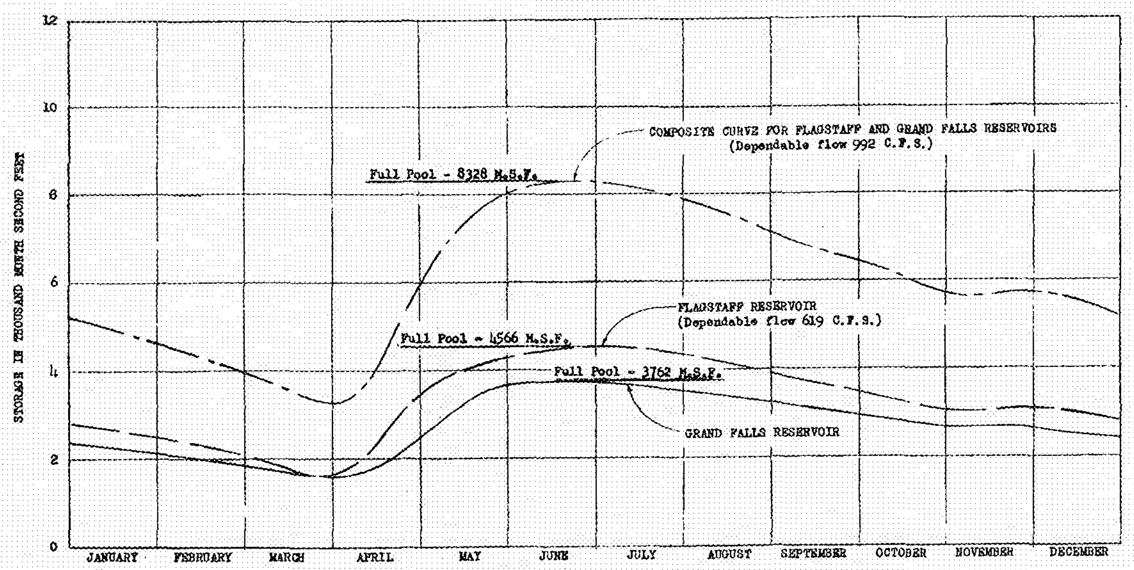
FLOOD DISCHARGE PROFILES AND TRIBUTARY CONTRIBUTIONS

NEW ENGLAND DIVISION BOSTON, MASS.
DECEMBER 1953


RIVER MILES ABOVE MOUTH OF KENNEBEC RIVER
MARCH 1936 FLOOD
PEAK DISCHARGE IN 1,000 C.F.S.
THE FORKS
BINGHAM
CARRABASSETT RIVER
SANDY R.
SKOWHEGAN
WATERVILLE
SEBASTICOOK RIVER
AUGUSTA
LOCAL
SEBASTICOOK RIVER
SANDY RIVER
CARRABASSETT RIVER
AUSTIN STR.
AUSTIN STREAM
DEAD RIVER
KENNEBEC RIVER ABOVE THE FORKS


RIVER MILES ABOVE MOUTH OF KENNEBEC RIVER
NOV. 1950 FLOOD
PEAK DISCHARGE IN 1,000 C.F.S.
THE FORKS
BINGHAM
CARRABASSETT RIVER
SANDY R.
SKOWHEGAN
WATERVILLE
SEBASTICOOK RIVER
AUGUSTA
LOCAL
300 GROSS
90 NET
SEBASTICOOK RIVER
970
250
95
SANDY RIVER
670
CARRABASSETT RIVER
395
80
AUSTIN STREAM
92
162
DEAD RIVER
878
KENNEBEC RIVER ABOVE THE FORKS
1240 GROSS
320 NET

A



RULE CURVES FOR REGULATION OF POWER STORAGE

B

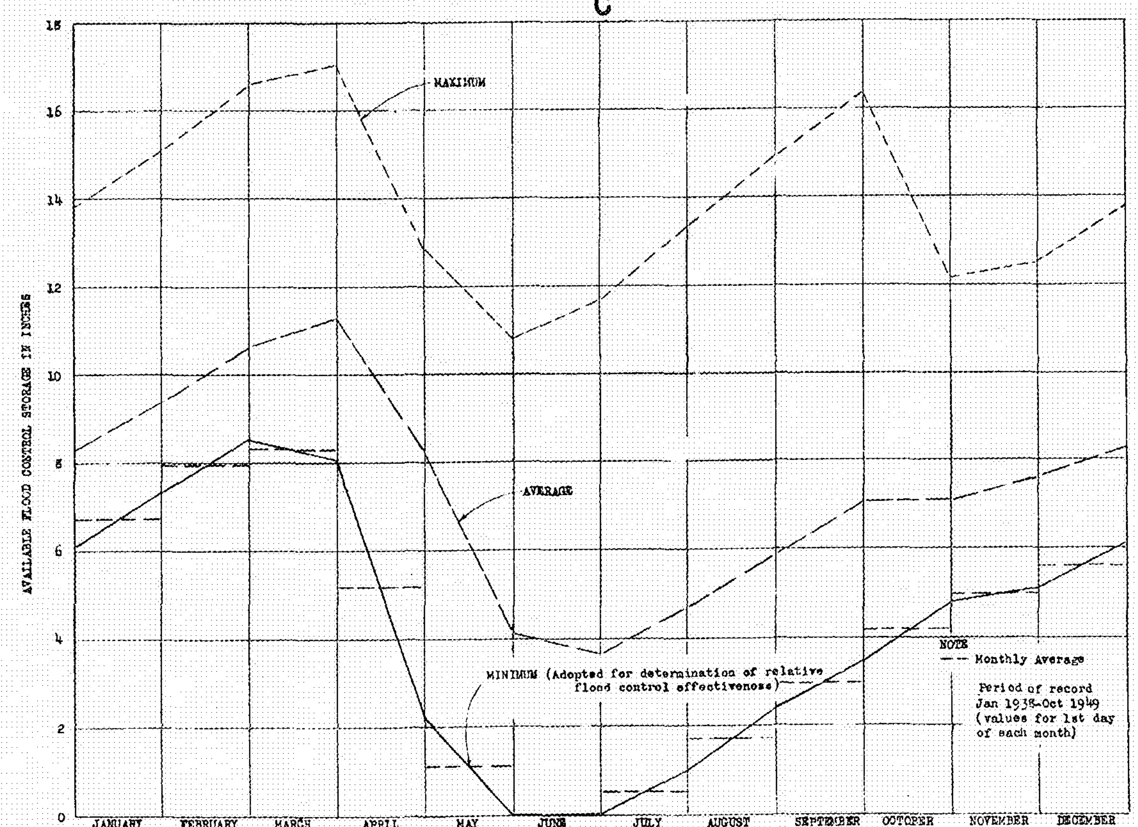
Year	January A	January B	February A	February B	March A	March B	April A	April B	May A	May B	June A	June B
1938	2,404	1,358	2,142	1,620	1,877	1,885	1,607	2,155	2,486	1,276	3,477	285
1939	2,411	1,351	2,138	1,624	1,859	1,903	1,605	2,157	1,801	1,961	3,390	378
1940	2,378	1,384	2,060	1,702	1,733	2,029	1,426	2,336	1,956	1,806	3,579	183
1941	2,404	1,358	2,138	1,624	1,871	1,891	1,600	2,162	2,484	1,278	2,329	1,433
1942	723	3,039	438	3,324	105	3,657	10	3,752	1,015	2,747	1,746	2,016
1943	1,534	2,228	1,272	2,490	1,005	2,757	755	3,007	925	2,837	2,662	1,100
1944	2,408	1,354	2,108	1,654	1,834	1,928	1,588	2,174	1,951	1,811	2,495	1,267
1945	1,342	2,420	1,428	2,334	1,172	2,590	1,605	2,157	3,265	497	3,762	0
1946	2,412	1,350	2,144	1,618	1,868	1,894	1,988	1,774	2,485	1,277	3,056	706
1947	2,134	1,628	1,960	1,802	1,874	1,888	1,602	2,160	2,365	1,397	3,762	0
1948	1,924	1,838	1,586	2,176	1,253	2,509	1,081	2,681	1,537	2,225	2,507	1,255
1949	1,126	2,636	932	2,830	627	3,135	459	3,303	1,183	2,579	1,379	2,383
Total (m.s.f.)		21,944		24,798		28,066		29,818		21,691		11,000
Avg. (m.s.f.)		1,829		2,066		2,339		2,485		1,808		917
(inches)		8.31		9.39		10.63		11.29		8.22		4.17
Max. (m.s.f.)		3,039		3,324		3,657		3,752		2,837		2,383
(inches)		13.81		15.10		16.62		17.05		12.89		10.83
Min. (m.s.f.)		1,350		1,618		1,885		1,774		497		0
(inches)		6.13		7.35		8.56		8.06		2.26		0

Year	July A	July B	August A	August B	September A	September B	October A	October B	November A	November B	December A	December B
1938	3,385	377	3,271	491	3,033	729	2,988	774	2,702	1,060	2,512	1,250
1939	3,467	295	3,238	524	2,951	811	2,677	1,085	2,687	1,075	2,631	1,131
1940	3,762	0	3,536	226	3,226	536	2,984	778	2,696	1,066	2,636	1,126
1941	2,098	1,664	1,897	1,865	1,602	2,160	1,307	2,455	1,080	2,682	999	2,763
1942	2,924	838	2,727	1,035	2,403	1,359	2,127	1,635	1,953	1,809	1,756	2,006
1943	3,437	325	3,341	421	3,230	532	2,983	779	2,703	1,059	2,639	1,123
1944	2,327	1,435	2,008	1,754	1,778	1,984	1,650	2,112	1,658	2,104	1,444	2,318
1945	3,762	0	3,540	222	3,229	533	2,986	776	2,697	1,065	2,637	1,125
1946	2,888	874	2,610	1,152	2,400	1,362	2,081	1,681	2,061	1,701	2,052	1,710
1947	3,762	0	3,457	305	3,229	533	2,898	864	2,556	1,206	2,245	1,517
1948	2,442	1,320	2,280	1,482	1,990	1,772	1,626	2,136	1,361	2,401	1,307	2,455
1949	1,188	2,574	822	2,940	474	3,288	156	3,606	-	-	-	-
Total (m.s.f.)		9,702		12,417		15,599		18,681		17,228		18,524
Avg. (m.s.f.)		808		1,035		1,300		1,557		1,566		1,684
(inches)		3.67		4.70		5.91		7.07		7.12		7.65
Max. (m.s.f.)		2,574		2,940		3,288		3,606		2,682		2,763
(inches)		11.70		13.36		14.94		16.38		12.19		12.55
Min. (m.s.f.)		0		222		532		774		1,059		1,123
(inches)		0		1.01		2.42		3.52		4.81		5.10

NOTE
1. Col. A denotes available power storage in M.S.F.
2. Col. B denotes available flood contrul storage in M.S.F.

APPLICATION OF RULE CURVE TO DETERMINE AVAILABILITY OF FLOOD CONTROL STORAGE

C



AVAILABLE FLOOD CONTROL STORAGE

D

Line	Description	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1	Available Flood Control Storage in Inches (From Chart C)	6.7	8.0	8.3	5.2	1.1	0	0.5	1.7	3.0	4.2	5.0	5.6	-
2	Monthly Flood Control Effectiveness in Percent (From Plate	100	100	100	65	14	0	8	28	50	70	83	94	-
3	Flood Potential Indices	1	1	13	28	35	9	1	1	4	1	4	2	100.0
4	Modified Flood Potential Indices [Line 3 x (100 - Line 2)]	0	0	0	9.8	30.1	9.0	0.9	0.7	2.0	0.3	0.7	0.1	53.6
5	Relative Flood Control Effectiveness (Line 3 - Line 4)													46.4%

DETERMINATION OF RELATIVE FLOOD CONTROL EFFECTIVENESS

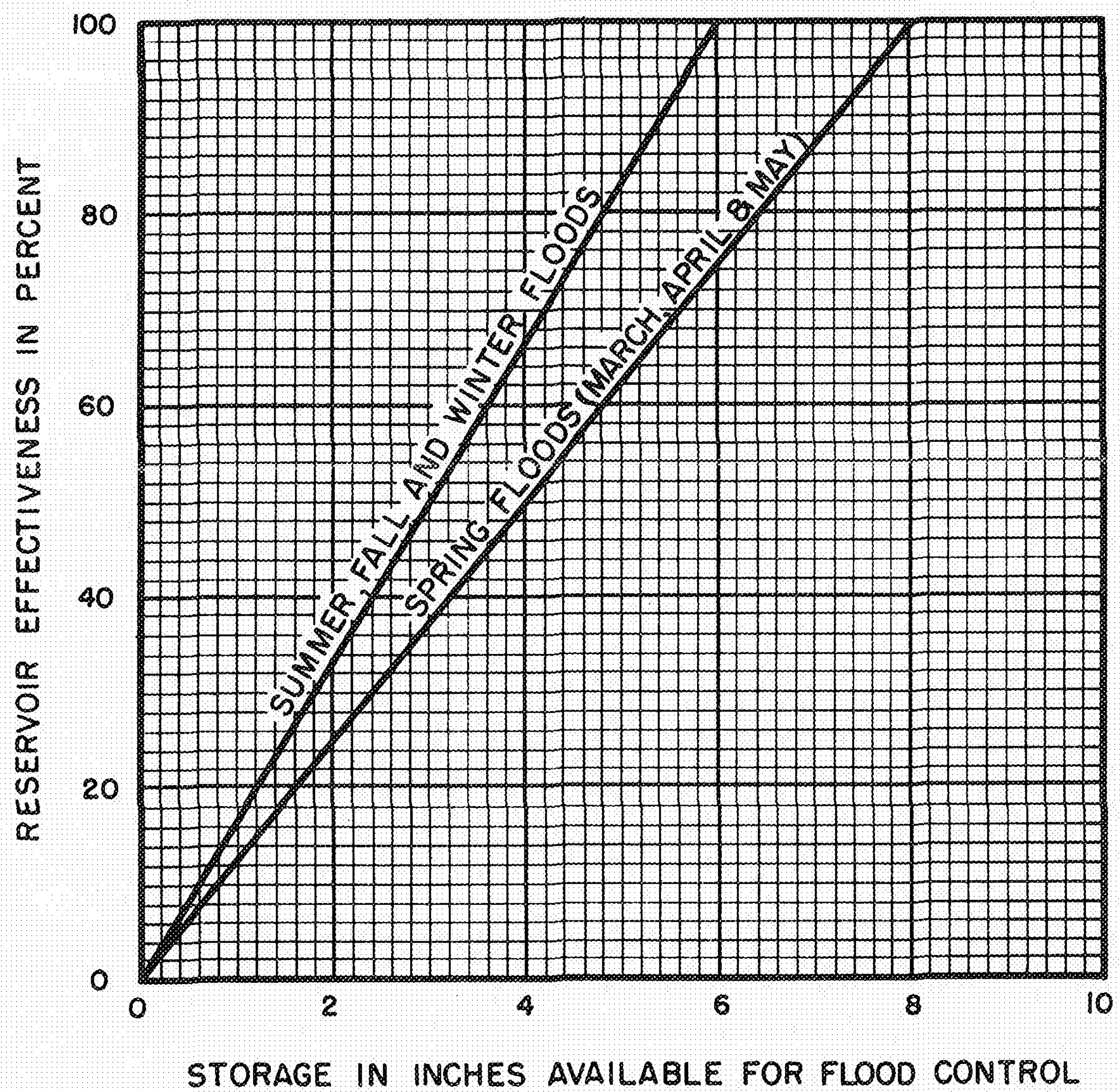
KENNEBEC RIVER BASIN

GRAND FALLS RESERVOIR

RELATIVE FLOOD CONTROL EFFECTIVENESS

NEW ENGLAND DIVISION, BOSTON, MASS.
MAY 1953

PLATE 4



NOTES

1. The above curves represent the percent effectiveness of a reservoir in relation to the seasonal variation in the storage available for flood control.

2. The curves are applicable only to projects operated for power purposes, and do not apply to reservoirs that include a definite allocation of storage for flood control.

NEW ENGLAND RIVER BASINS

FLOOD CONTROL EFFECTIVENESS

OF

POWER RESERVOIRS

ARMY NED BOSTON DEC. 1953

		MONTHS												
LINE	DESCRIPTION	J	F	M	A	M	J	J	A	S	O	N	D	ANNUAL
1	Available Flood Control Storage in Inches	1.4	1.8	1.1	0	0	0	0	0.1	0.5	0.6	0.1	0.6	-
2	Monthly Flood Control Effectiveness in Percent	23	30	18	0	0	0	0	2	8	9	2	10	-
3	Flood Potential Indices	1	1	13	28	35	9	1	1	4	1	4	2	100.0
4	Modified Flood Potential Indices [Line 3 x (100 - Line 2)]	0.8	0.7	10.7	28.0	35.0	9.0	1.0	1.0	3.7	0.9	3.9	1.8	96.5
5	Relative Flood Control Effectiveness (Line 3 - Line 4)													3.5%

KENNEBEC RIVER BASIN

GREENLEAF RESERVOIR

RELATIVE FLOOD CONTROL EFFECTIVENESS

NEW ENGLAND DIVISION-BOSTON, MASS.
MAY 1953

PLATE 5

LINE	DESCRIPTION	MONTHS												ANNUAL
		J	F	M	A	M	J	J	A	S	O	N	D	
1	Available Flood Control Storage in Inches	1.4	1.8	1.1	0	0	0	0	0.1	0.5	0.6	0.1	0.6	-
2	Monthly Flood Control Effectiveness in Percent	23	30	18	0	0	0	0	2	8	9	2	10	-
3	Flood Potential Indices	1	1	13	28	35	9	1	1	4	1	4	2	100.0
4	Modified Flood Potential Indices [Line 3 x (100 - Line 2)]	0.8	0.7	10.7	28.0	35.0	9.0	1.0	1.0	3.7	0.9	3.9	1.8	96.5
5	Relative Flood Control Effectiveness (Line 3 - Line 4)													3.5%

KENNEBEC RIVER BASIN

GREENLEAF RESERVOIR

RELATIVE FLOOD CONTROL EFFECTIVENESS

NEW ENGLAND DIVISION-BOSTON, MASS.
MAY 1953